DOOSAN Document Transmittal

Upper Trishuli-1 HEP (216MW)

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S. N.	REVIEW NOTE NO.	REVIEW STATUS	DWG. / DOC. NO.	REV.	DWG. TITLE / DOC. DESCRIPTION	REMARK
1	RN-0200	RR	UT1-C-020-CVL-TE-40012	0C	Physical Hydraulic Model Test Study Report of Weir and Dam	
2	RN-0201	AN	UT1-C-080-CVL-DG-59001	0C	Excavation and support drawing of Tailrace Outlet Gate Chamber	
3	RN-0202	AN	UT1-C-150-CVL-OT-54001	0	Technical Requirements for water pressure test of headrace tunnel	
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Legend of Review Status
A : APPROVED
AN : APPROVED AS NOTED
RR : RETURN FOR RESUBMISSION
FI : FOR INFORMATION

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Discipline : Civil

UPPER TRISHULI-1 HEP (216MW)			
Client	**Nepal Water and Energy Development Company Private Limited**		
Owner's Engineer	**Tractebel Engineering GmbH / Jade Consult**		
REVIEW NOTE			
Contractor	**Doosan Enerbility**		
Title of the Document	Physical Hydraulic Model Test Study Report of Weir		
Document No.	UT1-C-020-CVL-TE-40012	Revision	0C
Date of Documents	20.07.2022	Received Date	20.07.2022
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Comments

On 06 June 2022 the Contractor has submitted for review to the OE the document PHYSICAL HYDRAULIC MODEL TEST STUDY REPORT OF WEIR (UT1-C-020-CVL-TE-40012). The Owner's Engineer has reviewed the document and commented. A revised version '0C' of the model test study report was submitted on 20 July 2022. Related review comments are given below.

In addition, the Contractor has provided a reply statement (RC-0052) dated 20 July 2022 to each of the OE's comments (Review Note-0137 dated 14 June 2022). However, the contents of the reply statement should be incorporated into the next revised model test study report if and where appropriate.

Attachment 1, a document summarising the history of earlier model tests and explaining the rationale behind the new model tests is helpful. Arguments of the Contractor for changing the weir design to sluice design are logically explained and can, therefore, partially be shared by the OE.

Most of the OE's review comments of RN-0137, in particular related to chapters 6 and 7 have not been incorporated into this revised Model Test Study Report, version '0C', and, therefore, have been repeated in this Review Note.

While the review note contains a lot of details, below is a summary trying to point a way forward to arrive at a design for implementation.

Way forward

- The contractual design from DJKV was tested at Hydro Lab Pvt. Ltd., Lalitpur in 2013/2014. The tests had focussed on the arrangement of power intake and sluices to abstract the power flow and keep the flushing devices working. Approach flow conditions of the weir were obviously not subject of those studies; neither location nor orientation of weir axis had been subject to optimisation studies. The model study report suggested to cease power operation for floods exceeding the 2-yr return period, i.e. Q > 1,013 m^3/s. The report indicates increasing turbulent flows upstream of the dam for higher floods ($Q_{10\text{-yr}}$ = 1,602 m^3/s, $Q_{100\text{-yr}}$ = 2,337 m^3/s, $Q_{5000\text{-yr}}$ = 3,563 m^3/s). However, no problems with upstream water levels, energy dissipation in the stilling basin, and trashes and floating debris deficits for the final recommended layout were observed.
- The arguments for having the weir with stilling basin replaced by a flat-bottom sluice arrangement with apron are agreed to by the OE. The proposed rotation of the weir axis is explained. However, documentation of positive impact on flow conditions on the upstream side of the weir is limited to statements of avoiding overtopping of the dam crest while approach flow conditions remain unacceptable. Flow distribution between the three sluices has been documented as very unequal between the openings. This is not acceptable to the OE as a final design layout. There is insufficient testing and/or insufficient documentation.
- The base design scheme should be documented as reference regarding achieved improvements regarding approach flow conditions, hydraulics and the power intake and flushing efficiency of bed load.
- The model test report does not address the hydraulic conditions at power intake, regarding normal flow, sedimentation and flushing of bed load, etc. As these arrangements had been tested and optimised at Hydro Lab Pvt. Ltd. in 2013/2014, it requires reconfirmation of their suitability for the new layout (due to rotation of axis).
- The model test report does not include documentation of testing (i) of measures to improve flow distribution amongst the openings, (ii) the possibility of adding a fourth opening to the left to improve approach flow conditions, (iii) of improving approach flow conditions at the weir piers (alternative pier inclination/orientation into flow direction etc.), ie. alternative concepts which have been developed and tested by the hydraulic lab during the process of developing an optimum hydraulic configuration.
- Documentation of water levels, flow pattern and velocities (turbulence) at the individual openings should be carried out.
- The relevant design discharges to be studied should be agreed.

- The model test report mentioned and acknowledged increased erosion potential downstream of the weir on the left bank due to the axis rotation. Insufficient results are included in the report to provide input parameters for sizing of riprap and gabions.
- The length of downstream apron has not been discussed.
- If a different design flood downstream of the weir can be accepted under the contract should be clarified.

General

- The study report should be clearly structured and include (at least) the following:
- Model description and measurement techniques
- Model laws
- Test program
- Calibration of model
- Base design, as a start
- Modifications, as required
- Final recommended layout
- It has not been made clear which main discharges were selected for deciding on major modifications! Which indicators have been used to decide: water levels? Velocity and flow pattern mapping? Turbulence? Bed levels and scour depth?
- Documentation of results and measurements from various test series should be included as an Annex to the report.

Below are comments related to the individual chapters of the reviewed model test study report version '0C':

Table of Contents

- There is two-times 'Attachment-2' included in the ToC as well as at the end of the report. The attachment showing the intake drawings should be changed to 'Attachment-3'.

Chapter 2. Main Structures of Weir/Dam

- A clarification is needed to which design is described in the following: original DJKV Basic Design, or Preliminary Scheme-Alternative 1, or Recommended Scheme-Alternative 2?
- The design includes now a fish passage, separately for fish moving upstream and fish moving downstream along the left bank (Figure 2.1-1). However, it is not clear whether the structural elements located on the left bank downstream of the weir have been included in the model and the tests (the photos do not show such a structure, which may have a hydraulic impact on the flow conditions along the downstream left bank.

Chapter 3. Hydrological and Sediment Data

- Chapter 3.1: No such requirement of fulfilling a design flood standard (3) of a 200-year return flood for *'downstream energy dissipation and erosion control of the dam'* is included in Annex 13 Employer's Requirement, B1- 2.3 Design Flood, and does therefore not constitute an applicable design criterion.
- It is not clear whether the discharge series included in Table 3.6-1 have been subject to model tests, and if to which type of tests. A test schedule of the model tests carried out should be included.
- Chapter 3.7: How has the median value for d_{50} of sample 1 been defined? Figure 3.7-1 does not include data for this.

Chapter 4. Test Purposes and Contents

- According to the history (Annexure 1) of the model study, the main test purpose would have to be to demonstrate that the recommended layout with sluice and apron arrangement is performing better than the contractual Basic Design Scheme.
- The testing scope should include the hydraulic performance of weir with axis, openings and gates, but also include the performance of intake structure including sedimentation and flushing.
- Instead of 11 different test tasks now 5 tasks have been listed as "test contents": (i) cofferdam, (ii) discharge curves of gates, (iii) upstream flow pattern and optimisation of weir axis, (iv) flow conditions along spillway elements, and (v) downstream energy dissipation. However, neither testing concept nor test program has been provided.
- What was the testing purpose of the cofferdam?

Chapter 5. Model Design and Fabrication

- Chapter 5.1.2: Here the criteria selected for achieving a similarity in the model should be reported. Besides the dynamic similarity (Froude model law), the similarity of sediment material should be discussed. For bedload motion, shear stress plays a major role. Therefore, the similarity regarding Fr^* (Froude number of the grain) and the incipient velocity (Shields diagram) should be discussed.
- Chapter 5.2: When referring to the Terms of Reference, these should be included as an Annex.
- Chapter 5.3: Bedload particle size distribution is included as Figure 5.3-1. Is it true that there are no bed load particles of size <27 mm and 1 mm, respectively? From Figure 5.3-1 and the three samples shown a d_{50} diameter = 35 mm is derived, not 30 mm. Although the application of sediment particle size from two Chinese Rivers seems not appropriate. The model d_{50} diameter as read from Figure 5.3-1 is 0.5 mm not 0.6 mm. Thus, the resulting scale parameter is 60 rather than 50!
- Chapter 5.4: Model calibration had been carried out for annual average flow of 183 m^3/s, average monsoon flow 420 m^3/s, and 2-yr flood 1013 m^3/s. All floods tested in the model were bigger. Calibration results against the Contractor's mathematical 1-D model are marginal at best. Deviations are in the order between ±0.3 to ±0.8 m (left bank), ±0.7 (right bank). A little less for higher discharges.
- Calibration has been based on one-dimensional numerical model with roughness values transposed from two Chinese rivers for which there is little proof of similarity. However, no reference has been taken of water levels included in DJKV design report; reference has neither been made to the mathematical model generated for the CFD exercise. Do the results from these three hydraulic models for river match?
- Calibration of the model tests in 2013/2014 was carried out against HEC-RAS simulation data from DJKV. There is significant deviation between HEC-RAS simulation data and mathematical simulation applied by the Contractor in this study as shown in the table below.

Location	Section Name	Contractor Math. Model	DJKV Design	Difference
Q = 183 m^3/s				
Intake	Dam side	1239.77	1238.75	+1.02
D/S of weir	Down 3	1235.61	1234.65	+0.96
Flushing culvert	Down 20	1227.20	1227.40	-0.20
Q = 420 m^3/s				
Intake	Dam side	1241.23	1239.90	+1.33
D/S of weir	Down 3	1236.60	1235.79	+0.81
Flushing culvert	Down 20	1229.90	1228.80	+1.10
Q = 1013 m^3/s				
Intake	Dam side	1243.90	1242.41	+1.49
D/S of weir	Down 3	1238.86	1237.89	+0.97
Flushing culvert	Down 20	1232.37	1231.44	+0.93

Chapter 6. Test Results of Cofferdam Overflow

- The cofferdam described in the model test report (point 6) has obviously been designed for the 20-yr flood. However, the diversion concept actually adopted by the Contractor is different and considers floods outside the monsoon period only, and cofferdam crest elevation at 1253.0 masl. The cofferdam is foreseen to be overflown during the monsoon season, but at a lower crest elevation of 1250.0 masl. These two levels should be clearly mentioned and marked.
- Discharges studied for the cofferdam overflow are 2-yr, 5-yr, 20-yr and 100-yr floods, all well above the calibration scenarios! How do the results compare to the mathematical model?
- Chapter 6.1 and 6.2: Velocity profiles taken at the weir axis, upstream and downstream of it, should be compared prior and after inventions. Actual discharges passing the cofferdam are 745 m^3/s, 1,087 m^3/s, and 1,532 m^3/s. Flows
- Figures 6.1-1 to -4: It is not clear which velocities are surface velocities and which are bottom velocities. Flow velocities at the weir site decrease with increasing discharge!
- Picture 6.2-1: The photo shows a non-acceptable flow pattern due to its uneven distribution across the section and a deflection at the foot of the dam. What were the consequences out of this unacceptable flow pattern? Has the flow pattern been improved by trying various interventions?
- Pictures 6.2-1, 6.2-2, and 6.2-3: Photos included in the previous report and this version appear to be identical. However, discharge in the title of photo appear to have been adjusted! (772 m^3/s to 745 m^3/s, 1140 m^3/s reduced to 1087 m^3/s; 1635 m^3/s to 1532 m^3/s). Which report carries the correct discharge figures?
- Table 6.2-1: Water levels reported in the revised report are the same as in the earlier report but should now be valid for different discharge! Same is true for water surface profiles Figures 6.2-1 to -3. Which facts are correct?
- Chapter 6.2.2 (top of page 42):

  discharge through the cofferdam under the same working conditions is reduced by 268m^3/s to 295m^3/s compared with the original riverbed overflow, but due to the existence of the cofferdam, the local water head difference is increased, so the downstream discharge after the weir is slightly increased. In the upstream cofferdam, with the increase of the water level in

  Please, clarify the meaning. The discharge cannot increase!
- The explanation of different cofferdam heights, i.e. 1,253 masl vs. 1,250 masl need to be accompanied by figures in plan and section and included into this section of the report.
- Tests should be carried out for the correct cofferdam height (which in turn also may affect the flow distribution between tunnel and cofferdam) – or the consequences of having studied different layouts need to be incorporated into the text accordingly.
- Table 6.2-2 and the text trying to explain the changes in flow velocities are not understood.
- Chapter 6.3: Obviously, it is on the left bank upstream of the weir where significantly increased velocities have been recorded. What are the velocities against which the left bank should be protected?
- At the meeting with the LTA in May 2022, it was agreed to design the cofferdam as a hardfill dam. How do the tests carried out reflect on a layout of such hardfill cofferdam?

Chapter 7. Test Results of Physical Hydraulic Model of the Weir/Dam

- No data for tests with the Basic Design Scheme layout are presented!
- There is no test program given! What is the scope of testing? Which test series have been conducted? Which results have been recorded? (Water level? Flow velocities? Flow pattern? Discharge?). In order to prove (hydraulic) improvements, documentation of the Basic Design Scheme is required.

- Picture 7.1-1:

  The shape of the right bank guide wall and the 90°angle on the left bank cannot be found in any of the design layouts. Both have an impact on the flow pattern of the flow approaching the weir.

- Picture 7.1-2: The hydraulics at the weir are defined by water level and flow pattern. The flow situation as displayed in the picture for the 10,000-yr flood is not acceptable as final layout.
- Figures 7.2-1 and 7.2-2: both are titled “Optimisation Scheme 1 …”?
- Pictures 7.2-1 and -2: The right bank guide wall looks different than what is shown on the layout plan in Figure 7.2-2!
- Chapter 7.2.1: What are the findings and conclusions from the test series (which discharges were tested?) carried out for left bank approach flow improvement studies?
- Chapter 7.2.2: What is the conclusion from the test with a 4 m high weir step included (any drawing or sketch for explanation)? It is stated that the poor flow pattern improved with the weir for normal operational discharges up to 1,1013 m^3/s. Which discharge is relevant for the design?
- Chapter 7.2.3: The test results should be supported with velocity measurements and sketches of flow patterns, in particular describing the effect on the approach flow upstream of the weir and to the flow pattern downstream of the weir. Which discharges have been tested? Which discharge has been adopted as being relevant for the recommendation of the final rotation of the weir axis?
- This chapter and its layout need to be supported with related figures indicating the changes (such as Figure 7.2-3 in the previous report).
- How does the change of weir axis impact on the flow pattern at the power intake and regarding the flushing arrangements in front of the intake? The arrangement has been subject to extensive model testing and optimisation during the model tests in 2013/14.
- Chapter 7.2.4: Changing dimensions of flood openings is a major change. This should be supported through documentation. No photos, no velocity profiles, no water level profiles are included for this in the report.
- Did the reduction of the width of the openings resulted in larger piers? Or a new centre line? Or moving all openings to the right or to the left in the layout? The modification should be shown in a proper drawing. (The information now contained in Annexures 1, 2 and 3 need to be incorporated into the report accordingly!)
- What are the individual discharge figures for each of the three gate openings (left, centre, right)?
- Has an even flow distribution been achieved?
- Where have the water levels been measured?

The modified test results show that the reservoir water level is EL.1252.33m when three flood sluices are fully opened to discharge 10,000-yr return flood and EL.1255.40m when two flood sluices are fully opened to discharge 2,000-yr return flood, which meets the design and contract requirements.

Note: Photo shows 200-yr flood

- Chapter 7.2.5: The design standard listed as the 200-yr return flood deviates from the design floods chosen for the weir, which is 10,000-yr for the weir, 2,000-yr return flood for the case 1 gate malfunctioning, and 5,000-yr according to the DOED design standard.
- For which weir configuration (axis, size of openings) have the test been carried out?
- The flow pattern partially visible in Pictures 7.2-4 and 7.2-5 (included in chapter 7.2.3) cannot be regarded as the only proof of having achieved acceptable flow conditions for the final layout configuration (if this is actually the one recommended for implementation?).
- What are “scour materials” and “scour velocity of 8 m/s”?
- Formula 7.2-1: There are other formulas to define the begin of movement for riprap, which includes the turbulence in the dimensioning of riprap. Turbulence is a major factor when dimensioning rip rap. The scour velocity (velocity at which movement of riprap particles starts) has been calculated as 7.35 m/s. Has any turbulence factor been considered. How and which riprap has been designed at the end of the apron?
- How has the tailwater level been chosen, calibrated and selected in the model tests?
- Chapter 7.2.5.1: Picture 7.2-8: The flow at the left bank and the end of the “excavation area” is subject to high velocities. Reported velocities are 16 m/s, and between 7 m/s and 11.6 m/s at the right bank. This leads immediately to erosion and removal of riprap protection at the end of the apron! Consequences are not mentioned!
- Figure 7.2-4: The layout shows downstream of the apron a huge area lowered to elevation 1,235 masl on the left bank.
- What is the status of this area?
- What are the critical flow velocities at the downstream end?
- How does the flow pattern look like?
- Against which velocities the riprap has to be designed to be stable and not to erode the riverbed nor the riverbank?
- Is there any excavation foreseen in the upstream part?
- How is the layout coordination with the fish passage which is shown in earlier drawings along the left bank and entire length of the apron?
- These structures would be subject to high flow velocities during floods and possibly their stability endangered by erosion.
- Or are they arranged above a certain flood level? No elevation level has been included, e.g. in Figure 7.2-26.
- Chapter 7.2.5.2: Figure 7.2-12: What is the difference when compared to Figure 7.2-4? The change in design between the two layouts should be indicated.
- What slope inclinations are designed? What is the slope protection measure for the excavated slope section? Or against which load cases the slope has to be protected as derived from the model tests?
- Pictures 7.2-8 and 7.2-9 are taken from different viewpoints. A real comparison of flow conditions is therefore not provided by these photos. No significant difference is visible.
- Chapter 7.2.5.3: Four (4) modifications have been studied.
- It is not clear which of these modifications have improved the hydraulic performance?
- Which of the measures are recommended for implementation?
- The proposal of a flip bucket at the downstream end of the apron is not clear. It requires a layout drawing and a longitudinal section to be shown.
- Proper layout drawings and sections should be presented.
- Photographs of the modifications (in dry condition) would help to visualise the modifications.
- Missing Chapter 7.3: A chapter ‘*Test results of Basic Design Scheme*’ is missing (and should be inserted into the report at the appropriate part in the text). Chapter 7.1 – ‘*Test results of preliminary*

scheme', chapter 7.2 – '*Flow pattern optimisation test in reservoir area*'. The next chapter - which is however missing – should be '*Test results for optimised and recommended scheme layout*'!

- Chapter 7.3.1: Third paragraph: the text from "Figure 7.3-1 shows …" and following four paragraphs and its meaning is not clear. Is this a misprinting? Or mistyping?
- What was the downstream water level on the apron for fully open gates? Any impact from tailwater level? Is there a downstream rating or tailwater curve? (explanations given to earlier OE's comments to be incorporated into the report)
- Table 7.3-1, 7.3-2, 7.3-3, 7.3-4, 7.3-5 and Figures 7.3-1, 7.3-2 are only valid if measured for the individual gate. The presentation in the report strongly suggests that this is the result of a package of 3 gates operated together with very uneven flow conditions between the three openings.
- Are the discharges released through the three gates even? The photos and comments on observation during the model tests give a strong impression that discharge at the three gates are very uneven. Flow velocities should be measured during the tests to determine discharge distribution through the three openings.
- Chapter 7.3.2: In this chapter it is confirmed that flow velocities, and thus the discharges through the three openings are not equal. This invalidates the "calibrated" discharge capacities for individual gates reported in Chapter 7.3.1 above.
- There is no optimisation reported trying to improve flow conditions for and distribution of the three openings. Therefore, the understanding of the OE is that this is a preliminary result of the investigations. Are there final investigations to follow?
- Chapter 7.3.3: With non-acceptable, non-balanced, non-equal flow distribution through the three openings, the test results for pressure distribution only for the centre opening cannot be accepted as representative.

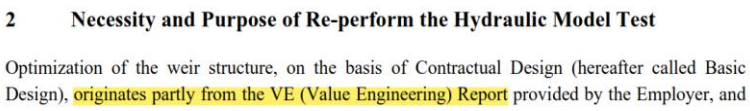
Chapter 8. Conclusions and Suggestions

- 11 points, which reflect the main scope of the model tests, are listed: (i) existing flow velocities, (ii) overflow condition at cofferdam, (iii) approach flow conditions at weir for preliminary design scheme, (iv) adjustment of weir axis, (v) size of openings, (vi) flow through flood gates, (vii) flow velocity at sluices, (viii) pressure condition at bottom slab, (ix) apron for energy dissipation, (x) flip bucket at end of apron, and (xi) large size of riprap at end of apron. However, for most of the above points studied, documentation included into the report is poor.
- Cofferdam:
    - Necessity of riverbed protection downstream of upstream cofferdam on left bank has been identified. Design recommendation is pending.
    - No recommendation regarding improvement of cofferdam hydraulics.
- A summary of the final hydraulic project layout configuration as included in Figure 7.2-24 should be included in this chapter, or a direct reference to the drawings of Attachments 1 and 2 be given..
- Hydraulics of the „preliminary layout" have been described as insufficient. A 15° anti-clockwise rotation of the weir axis has been recommended. However, approach flow and discharge distribution amongst the three openings remain hydraulically unsatisfactory. Impact on hydraulics and sediment flushing at the power intake has not been tested.
- Size of the openings has been reduced to 10 m wide by 17 m high. However, approach flow conditions did not improve and discharge distribution amongst the openings remains unsatisfactory.
- Modifications applied to the right bank guide wall should be clearly shown (situation at basic scheme design vs. recommended design).
- Why reference to the 100-yr flood only regarding the flow velocity? Flow velocities at the three openings are very different. How can that be improved?
- Flow velocities at the end of the apron are greater than 12 m/s! What does this mean in consequence for the riprap protection?
- Pressure condition at sluice bottom slab: the conditions are varying for the three openings, they are fluctuating over time (impact of turbulence!), and they are different for the tested discharges. Have the velocities and pressure been measure over time? What is the average, what are the magnitude

of variations? While the presented results reflect the middle section, they do not represent the very different situation in the other two openings.

- What is the required length of the apron? At which distance are the flow velocities similar to the natural conditions? This would be a proper criterion for the length of the apron and to be proven by the model test.
- The different alternatives of apron modifications are not clearly presented (drawings, photos). In general, the flow velocities at the end of the apron appear still to be much higher than in the natural situation. The apron should be extended until flow velocities have decreased to a situation comparable to the natural condition.
- The Apron modification scheme 4 with flip bucket: 1:4 at the end of apron to the downward cut (???) and slope excavation scheme 2 should be clarified.

Attachment-1:



2 Necessity and Purpose of Re-perform the Hydraulic Model Test

Optimization of the weir structure, on the basis of Contractual Design (hereafter called Basic Design), originates partly from the VE (Value Engineering) Report provided by the Employer, and

- Layout of the weir was not part of the VE!
- Reference to Attachment-1 has to inserted at the appropriate places in the text, or directly inserted into the model study report, where appropriate.

Attachment-2:

- It is not stated which design is shown in this attachment. The OE supposes it is intended to show the recommended design scheme. This needs to be clearly stated. There also needs to be reference to this attachment at appropriate places in the main text itself.

Attachment-3:

- It is not stated which design is shown in this attachment. The OE supposes it is intended to show the recommended design scheme incorporating a 15° anti-clockwise rotation of the weir axis, which has direct implications for the power intake drawings and the tunnel alignment connecting to the headrace tunnel. This needs to be clearly stated.

Remarks

- Physical hydraulic model tests had already been carried out in 2013/2014 in Kathmandu at the Hydro Lab Laboratory in Lalitpur. The tests were carried out for a basic design scheme and focussed on the power intake arrangement and guide walls improving the hydraulics of the original DKJV design which included a weir with radial gates and stilling basin. It could be helpful for the development of a final layout to draw on the experiences from the laboratory and its personnel, if available.
- It is not clear what is the difference in layout arrangements between the contractual ‘basic design scheme’ and the recommended design scheme resulting from the 2022 model tests? This in particular with regards to weir axis, weir orientation, location of gates and location of power intake tower.
- There is no summary which presents the improvements and/or advantages of the recommended design scheme 2022!

DISCLAIMER

Any approval will not release the Contractor from any of his obligations under the Contract. Despite the Engineer's approval the Contractor remains fully responsible for design, calculation, dimensioning, supply and installation without limitations.

Dr Frank Negrassus, hydraulic specialist	Sebastian Beck, Chief Design Engineer